

# PATENT APPLICATION

## Recording Medium, Optical Disk Apparatus and Writing Method

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RECORDING MEDIUM, OPTICAL DISK APPARATUS  
AND WRITING METHOD

BACKGROUND OF THE INVENTION

The present invention relates to a technique for recording information onto an optical disk by using a laser beam.

5           In a rewritable optical disk such as DVD-RAM, DVD-RW, CD-RW and a write once disk such as DVD-R and CD-R, information is recorded by applying a laser beam onto the disk recording surface. As the laser beam application method for forming a recording mark on the  
10 recording surface of the optical disk, there is a CD-R method for forming a recording mark by applying a recording pulse having time width according to the length of the recording mark, a DVD-RAM method for making the recording mark forming pulse comb-shape so  
15 as to control head accumulation and to form an optimal recording mark, and the like. The waveform of the recording pulse to obtain the optimal recording mark is called write strategy.

Fig. 1 schematically shows a write strategy  
20 of 4.7 GB-capacity DVD-RAM (hereinafter, referred to simply as DVD-RAM) which is one of the rewritable optical disks. Fig. 1 shows the write strategy when recording 11T (T is a recording clock cycle) mark. As shown in the figure, the DVD-RAM write strategy

consists of a first pulse defined by TSFP, TEF, TFP, a repeated pulse (multi pulse) defined by TMP, and a last pulse defined by TSLP, TELP, TLP. It should be noted that the laser power level may be binary and tertiary.

5 Here, for simplification, the binary case is shown.

The first pulse of this write strategy may be defined by "a method for defining the waveform rise and fall end absolute time by the TSFP and TEF" or "a method for defining the rise edge absolute time and the pulse time width by the TSFP and TFP."

Moreover, the last pulse also may be defined by two methods: "a method for defining the edge absolute time by the TSLP and TELP" or "a method for defining the fall edge absolute time and the pulse time width by the TELP and TLP".

The TSFP which is a value deciding the time position of the front edge of the first pulse and the TELP which decides the time position of the rear edge of the last pulse are varied according to the recording mark length and the preceding and the following space length. This is because affect of the heat accumulation and heat diffusion by the laser beam when recording a mark varies depending on the recording mark length and the preceding and following space length.

25 Fig. 2 shows an example of adjustment table of TSFP and TELP. The 3T, 4T, 5T,  $\geq 6T$  (6T or more) arranged in the longitudinal direction of the TSFP table represent the space length immediately before the

recording mark while the 3T, 4T, 5T,  $\geq$  6T (6T or more) in the lateral direction represent mark length.

Similarly, in the TELP table, the 3T, 4T, 5T,  $\geq$  6T (6T or more) arranged in the longitudinal direction

5 represent the space length immediately after the recording mark while the 3T, 4T, 5T,  $\geq$  6T (6T or more) in the lateral direction represent mark length to be recorded. Since the values in the adjustment table shift the edge of the write strategy decided by TSFT  
10 and TELP, hereinafter these tables will be referred to as shift tables. Moreover, values deciding the edge timing of the recording waveform such as TSFP described in Fig. 1 and the aforementioned shift tables will be referred to as recording parameters (parameter group).

15 The method of modifying the write strategy by the relationship between the recording mark and the space length is used not only in the DVD-RAM but also in the other rewritable phase-change type medium DVD-RW, CD-RW and in the write once type pigment type medium  
20 DVD-R, CD-R, and the like.

Conventionally, for the recording parameters, the value which a medium manufacturer considers optimal under the condition of the constant linear velocity is recorded on the medium and provided. Since the write  
25 strategy form including the power level and the timing and the optimal values of the recording parameters such as shift tables significantly vary depending on the recording medium composition and material, it has been

considered preferable that the medium manufacturer suggest the write strategy. For example, in the DVD-RAM, the aforementioned recording parameters are recorded in the physical format information (PFI) area  
5 in the control data zone arranged in the lead in area. It should be noted that the aforementioned conventional technique is disclosed in JP-A-2003-085753 and JP-A-2002-260226.

#### SUMMARY OF THE INVENTION

10 In the same as the recording medium has irregularities in the composition and material, an optical disk recording apparatus (hereinafter, referred to as "drive") also has irregularities in the laser output power and circuit characteristics. Accordingly,  
15 the optimal recording parameter in a particular drive may not be the optimal recording parameter in another drive. Especially the recording parameter recorded on the medium is an optimal parameter when recording is performed at a particular linear velocity. When  
20 recording information onto the recording medium at a linear velocity other than the particular linear velocity, the recording parameter recorded on the medium in advance is not optimal. Accordingly, when performing recording at a linear velocity other than  
25 the linear velocity corresponding to the optimal parameter recorded in advance, it is preferable that the drive decide the optimal parameter at the linear

velocity.

However, in the drive for recording information on a recording medium where an optimal recording parameter at a particular linear velocity is described, conventionally, no consideration has been taken on the method to obtain an optimal recording parameter at a linear velocity other than the particular linear velocity at the drive side.

It is therefore an object of the present invention to provide a method for preferably deciding a recording parameter provided by a medium manufacturer and a method to obtain, by using this recording parameter, a recording parameter at a linear velocity other than the linear velocity estimated by the medium manufacturer.

Next, explanation will be given on the variable velocity writing method which switches the write strategy when a predetermined linear velocity is reached.

In general, the heat diffusion amount at the front edge of the recording mark is proportional to the recording linear velocity while the heat accumulation amount at the rear edge is proportional to the square root of the recording linear velocity. Moreover, an energy amount given to the recording medium by the laser beam irradiation of a predetermined power level such as a recording power and an erase power is proportional to the laser beam irradiation power level

per unit area and substantially proportional to the recording velocity.

However, if the write strategy is different, the aforementioned proportional relationship between the heat diffusion amount, heat accumulation amount, recording laser power and the recording velocity is broken. Accordingly, a recording parameter at an arbitrary linear velocity obtained by simple interpolation method (interpolation method, extrapolation method) of an optimal recording parameter at a plurality of linear velocities recorded in the recording medium in advance, generally, cannot be an optimal recording parameter. For this, in the writing method in which the recording linear velocity is successively changed like CAV (constant angular velocity) recording, it is difficult to realize a preferable variable speed recording by successively calculating the optimal recording parameter at the respective recording linear velocities.

During the CAV recording, it is possible to use a writing method for switching the write strategy each time a predetermined linear velocity is reached. However, when such a writing method is employed, the write strategy is abruptly switched at a predetermined position and as has been described above, the aforementioned proportional relationship becomes discontinuous. Accordingly, the same mark (for example, 3T mark) changes its shape before and after the

strategy switching. Thus, when reproducing data immediately after the write strategy switching position, the equalizer, group delay and other reproduction parameter characteristic switching cannot follow the  
5 recording mark characteristic switching and there arises a problem of deterioration of the reproduction quality when the areas before and after the write strategy switching are reproduced continuously.

A second object of the present invention is  
10 to assure continuity of recording parameters, assure continuity of the recording mark shape, and improve the reproduction quality.

In order to achieve this object, there is provided a recording medium on which information is  
15 recorded by applying a laser pulse to form a mark on a recording layer, wherein identification information is recorded to indicate that a plurality of control parameter groups are recorded which have the laser pulse power level changing timing substantially  
20 proportional to the recording velocity for recording a mark of length not smaller than the laser spot diameter in the recording layer.

According to another aspect of the invention, there is provided a recording medium on which  
25 information is recorded by applying a laser pulse to form a mark on a recording layer, the recording medium containing control parameters recorded for respective linear velocities decided by: a step of recording a



first mark having a length not smaller than the laser spot diameter in the recording layer at a first linear velocity, a step of recording a second mark having a length equivalent to the first mark at a second linear  
5 velocity, a step of calculating a voltage value change amount at two points at a distance  $T_s$  ( $T_s < T_m/2$ ) in the time axis direction before and after the time position reference  $T_m/2$  from the front edge of an electric signal waveform obtained by reproducing the  
10 first or the second mark at a predetermined linear velocity and having a time width  $T_m$ , and a step of deciding a control parameter of the laser pulse power level change timing so that the aforementioned change amount is substantially constant during recording at  
15 any of the linear velocities.

According to still another aspect of the present invention, there is provided an optical disk apparatus comprising a laser for applying a laser beam onto an optical disk, laser control means for  
20 controlling the laser, and rotation drive means for driving the optical disk to rotate, so that a laser pulse is applied onto a recording layer of the optical disk to form a mark, thereby recording information on the optical disk, wherein the laser control means  
25 changes recording linear velocity successively or stepwise for continuous recording by using such a control parameter that a change timing of the power level of the laser pulse for recording a mark having a

length not smaller than the laser spot diameter in the recording layer is substantially proportional to the recording linear velocity.

According to yet another aspect of the

5 present invention, there is provided an optical disk apparatus comprising a laser for applying a laser beam onto an optical disk, laser control means for controlling the laser, and rotation drive means for driving the optical disk to rotate, so that a laser

10 pulse is applied onto a recording layer of the optical disk to form a mark, thereby recording information on the optical disk, wherein continuous recording in which the recording linear velocity changes successively or stepwise is performed by using control parameters for

15 respective linear velocities decided by: a step of recording a first mark having a length not smaller than the laser spot diameter in the recording layer at a first linear velocity, a step of recording a second mark having a length equivalent to the first mark at a

20 second linear velocity, a step of calculating a voltage value change amount at two points at a distance  $T_s$  ( $T_s < T_m/2$ ) in the time axis direction before and after the time position reference  $T_m/2$  from the front edge of an electric signal waveform obtained by reproducing the

25 first or the second mark at a predetermined linear velocity and having a time width  $T_m$ , and a step of deciding a control parameter of the laser pulse power level change timing so that the aforementioned change

amount is substantially constant during recording at any of the linear velocities.

According to yet still another aspect of the present invention, there is provided a writing method  
5 for recording information on an optical disk by applying a laser pulse on a recording layer of the optical disk so as to form a mark, wherein recording linear velocity is changed successively or stepwise for continuous recording by using such a control parameter  
10 that a change timing of the power level of the laser pulse for recording a mark having a length not smaller than the laser spot diameter in the recording layer is substantially proportional to the recording linear velocity.

15 The present invention assures continuity of the shape of a reproduction waveform, thereby enabling stable reproduction. Moreover, it is possible to easily calculate a recording parameter at a recording velocity other than the recording velocity where the  
20 recording parameters provided by a medium manufacturer are defined, from the recording parameters provided by the medium manufacturer. Accordingly, when performing CAV recording, it is possible to calculate a preferable recording parameter.

25 Moreover, for a drive manufacturer, it is possible to simplify the write strategy setting method when realizing a high velocity recording by the CAV recording, reduce the drive development time, and

reduce the learning time when adjusting the write strategy in the drive.

Moreover, by using the procedures of the present invention in the drive, it is possible to  
5 calculate the write strategy and the recording parameter coping with the variable velocity recording so as to realize a variable velocity recording such as CAV recording in a medium not having any recording parameters provided by a medium manufacturer coping  
10 with the variable velocity recording. Furthermore, by referencing the variable velocity recording flag, it is possible to easily identify a medium supporting the variable velocity recording and reduce the write strategy learning time when performing the variable  
15 velocity recording.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

## 20 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 schematically shows 11T mark recording waveform of a 4.7 GB DVD-RAM.

Fig. 2A and Fig. 2B show an example of recording parameter control table.

25 Fig. 3A and Fig. 3B are an example of a 10T mark reproduction waveform and its schematic diagram.

Fig. 4 schematically shows an example of

relationship between the recording velocity and recording parameter.

Fig. 5A and Fig. 5B are an example of a 10T space reproduction waveform and its schematic diagram.

5 Fig. 6 shows a waveform of a 4.7 GB DVD-RAM reserved area.

Fig. 7A and Fig. 7B are an example of a 10T mark reproduction waveform and its schematic diagram.

Fig. 8 schematically shows an example of 14T  
10 mark reproduction waveform and sample pulse.

Fig. 9 schematically shows an example of 14T mark reproduction waveform and sample system.

Fig. 10 is a flowchart showing a drive operation sequence.

15 Fig. 11 is a block diagram of a drive according to the present invention.

Fig. 12 schematically shows an example of relationship between the recording velocity and the normalization recording parameter.

## 20 DETAILED DESCRIPTION OF THE EMBODIMENTS

### [Embodiment 1]

Explanation will be given on the first embodiment by using the DVD-RAM as an example. As has been described above, in the DVD-RAM, the recording  
25 parameter is selected by a medium manufacturer and shipped.

Currently, as the DVD-RAM standard, double

speed (hereinafter, referred to as "2x") recording standard and triple speed (hereinafter, referred to as "3x") recording standard are released. Release of five-times speed (hereinafter, referred to as "5x") recording standard is expected. That is, the 5x recording disk (hereinafter, referred to as DVD-RAM 5x) is probably provided with the 2x recording and 3x recording parameter, considering the compatibility with a lower apparatus. Moreover, by using the recording parameters of the respective recording velocities, in the 5x recording drive, it is possible to perform CAV recording with recording velocity of 2x at the innermost circumference and 5x at the outermost circumference. An example of recording parameter decision procedure in the respective recording velocitys for recording onto the DVD-RAM will be explained below.

#### Procedure 1. Recording parameter estimation

In the procedure 1, firstly, recording parameters at the respective recording velocities provided, i.e., 2x, 3x, 5x are tentatively set in the linear value of the recording velocity. This is because in order to cope with the variable speed recording such as CAV recording, linearity is required between the recording parameters provided and the recording velocity.

Procedure 2. Long mark reproduction waveform adjustment and basic recording parameter linearity

check

In the procedure 2, by using the tentative recording parameters set in the procedure 1, a long mark of 6T or more is recorded at each recording velocity and reproduction waveforms obtained when reproduction is performed at a constant speed are compared.

In general, in optical disk reproduction, when reproducing a mark almost equal to or greater than a spot diameter, the reproduction signal amplitude level is saturated and the waveform shift difference generated by the spot shape difference is small. In the case of the DVD-RAM of the present embodiment, the diameter of beam for reproduction is  $0.86 \mu\text{m}$  and the amplitude value of the 6T signal or above equivalent to the  $0.84 \mu\text{m}$  length which is almost identical to the beam diameter is almost constant. Accordingly, the recording parameter initial adjustment is performed by using a waveform of a long mark of the 6T or above as a reference and after this, the recording parameter for forming a short mark is adjusted. This reproduction velocity may be the lowest reproduction velocity defined by the medium.

Fig. 3 shows a reproduction waveform 301 of a long mark (10T) recorded at a certain recording velocity in the DVD-RAM. Fig. 3 is an example of the 10T waveform and the low portion of the waveform indicates a dark portion (mark portion). Moreover, the

reproduction velocity is 2x, and the reproduction system parameter is the standard parameter described in the DVD-RAM specification. Fig. 3B shows a waveform schematically extracted from the waveform of Fig. 3A.

5 Here, the waveform is separated to the front part and the rear part with respect to the center of the recording mark waveform, i.e., the 5T position 302 in this case. The minimum value 303 of the front part and the minimum value 304 of the rear part are extracted

10 and the inclination A2x of the straight line 305 connecting the both waveform positions is calculated. The inclinations at 3x and 5x are also calculate to obtain A3x and A5x. A medium manufacturer decides the recording parameters provided as follows. That is, the

15 recording parameters at the respective velocities are adjusted so that the values of A2x, A3x, A5x are almost identical (preferably within a range of  $\pm 10\%$ ).

It should be noted that here, adjustment has been made according to the inclination of the minimum

20 value of the front part and the minimum value of the rear part. However, the present invention is not to be limited to this. it is also possible to calculate an inclination between two points positioned at a predetermined distance from the mark center and make

25 adjustment according to the inclination.

During this adjustment, linearity for the recording velocity is checked for the recording parameter which is advised not to be adjusted in the



drive in the medium specification (hereinafter,  
referred to as basic recording parameter). In the DVD-  
RAM of the present embodiment, "TFP, TMP, TLP, TCL,  
TEFP, TSLP" in Fig. 1 and "TSFP (201 in Fig. 2) when a  
5 mark of 6T or above follows the space of 6T or above,  
TELP (202 in Fig. 2) when space of 6T or above follows  
a mark of 6T or above" are the basic recording  
parameters.

As has been described above, the  
10 aforementioned basic recording parameters can all be  
set so that they have a logically linear relationship  
with respect to the recording velocity. However, a  
slight error may be generated in each recording  
parameter value by the recording parameter decision  
15 procedure and the value rounding.

For this, as shown in Fig. 4, from the  
recording parameter value 401 obtained by the highest  
recording velocity (5x recording in this case) and the  
recording parameter value 402 obtained by the lowest  
20 recording velocity (2x recording in this case), between  
them, the recording parameter value 404 of the velocity  
(3x recording in this case) at which a medium  
manufacturer provides a recording parameter is  
calculated. A difference  $\Delta Pt406$  between the value thus  
25 obtained and the aforementioned velocity obtained in  
the procedure 1 and procedure 2, i.e., 3x recording  
parameter value 403 in this case is calculated.

This  $\Delta Pt$  is compared to an error allowance

value defined for each recording parameter. If the  $\Delta Pt$  is not greater than the error allowance value, the adjustment is completed. If the  $\Delta Pt$  is greater than the error allowance value, the recording parameter is  
5 again adjusted by the mark reproduction waveform. After this adjustment, if the inclination at each recording velocity of reproduction waveform of the long mark defined above and the linearity of the basic recording parameter do not satisfy a predetermined  
10 condition, the recording medium is improved by considering the recording medium composition and material.

It should be noted that the recording parameter condition extraction in the above is  
15 performed by simultaneously comparing to the data to clock jitter (hereinafter, referred to simply as jitter) during reproduction of the recording waveform, reproduction waveform asymmetry, and other specification values.

20                    Procedure 3. Shift table, power level adjustment

In the procedure 3, after adjustment of the recording parameter, adjustment of recording parameters other than the basic recording parameters adjusted in  
25 the procedure 2 at each recording velocity is performed. In this embodiment, the area other than 201 and 202 of the shift table in Fig. 2 and the recording power level adjustment correspond to this adjustment. As the

adjustment method, it is possible to employ a method to minimize the reproduction jitter. For example, it is possible to employ the technique defined in the medium specification such as the DVD-RAM.

5           It should be noted that the basic recording parameters adjusted in the procedure 2 are not modified in the procedure 3. This is for maintaining the shape of the long mark reproduction waveform and the recording parameter linearity for the recording  
10 velocity in the procedure 2.

          Procedure 4. Recording parameter linearity check

          In the procedure 4, linearity for the recording velocity is checked for the recording  
15 parameter at each recording velocity extracted in the procedure 3. In the DVD-RAM of the present embodiment, linearity for the recording velocity is checked for the recording parameters shown in Fig. 1 and the TSFP and TELP shift tables shown in Fig. 2.

20           When the linearity of basic recording parameters is guaranteed in the procedure 2, these recording parameters can all be set so that they have theoretically linear relationship with the recording velocity. However, similarly as in the procedure 2, an  
25 error may be involved by rounding the recording parameter values and accordingly, in the same way as the procedure 2, an allowable error value is set for each recording parameter so as to check the linearity.

Procedure 5. Setting flag for variable  
velocity recording

Depending on the recording medium film  
composition and material, there is a case that an  
5 appropriate parameter cannot be selected by the  
adjustments of the procedures 1 to 4. Such a medium  
cannot cope with the variable velocity recording such  
as the CAV recording and should be distinguished from  
those which satisfy the adjustments of the procedures 1  
10 to 4. The procedure 5 sets a judgment flag indicating  
presence/absence of a recording parameter adjusted by  
the procedures 1-4 so as to distinguish it.

For example, in the DVD-RAM standard, bit 613  
and after in the RFI1 sector where the recording  
15 parameters provided by a medium manufacturer are  
recorded are reserved (empty bits). Here, the 1-bit  
judgment flag can be set for distinguishing.

In the drive, when inserting a medium, it is  
checked whether the judgment flag is present. When the  
20 bit is 1, the medium is recognized as a variable  
velocity recording medium and at a recording velocity  
between the medium lowest recording velocity and the  
highest recording velocity, recording is performed by  
using a recording parameter obtained by linear  
25 interpolation or the recording parameters provided by a  
medium manufacturer for the lowest recording velocity  
and the highest recording velocity. In the case of the  
DVD-RAM 5x recording medium of the present example,

from the recording parameters provided by the medium manufacturer for the 2x recording and 5x recording, it is possible to calculate the recording parameters at the recording velocities between them such as 2.5x, 3x, 5 and 4x.

By using the procedures 1-4 shown in this embodiment, it is possible to easily calculate recording parameters of recording velocities other than those corresponding to the recording parameters provided by a medium manufacturer from the recording parameters provided by the medium manufacturer. When performing continuous recording in the CAV recording where the recording velocity is successively changing, it is possible to always calculate an optimal recording parameter. Moreover, a high quality CAV recording is guaranteed by the optical disk of the present embodiment and a user can perform data recording of a high quality.

Moreover, by providing a flag indicating the employment of the procedures 1-4, it is possible to know whether the recording medium can cope with the CAV recording and an appropriate recording control can be performed. That is when the recording medium is judged to cope with the CAV recording, CAV recording is performed and when the recording medium is judged not to cope with the CAV recording, CAV recording is not performed. Moreover, for a drive manufacturer, it is possible to simplify the write strategy setting method

when realizing a high velocity recording by CAV recording, which reduces the drive development time and the learning time during the write strategy adjustment.

It should be noted that when employment of  
5 the procedures 1-4 is guaranteed by the medium standard, there is no need of checking the recording medium whether it can cope with the CAV recording and no flag is required.

Furthermore, even when areas recorded with  
10 different recording velocities are adjacent to each other, the reproduction waveform shapes match and accordingly, it is possible to perform stable reproduction.

[Embodiment 2]

15 Next, explanation will be given on a second embodiment. The second embodiment also sets recording parameters in the same way as the first embodiment. However, the procedure 2 is different from that of the first embodiment. Hereinafter, explanation will be  
20 given on the procedure 2.

In the procedure 2 of the first embodiment, by monitoring the reproduction waveform of the long mark of 6T or above recorded by using the recording parameters of different velocities, the inclination of  
25 the mark portion is substantially matched between the recording velocities. In the present embodiment, the inclination of the reproduction waveform of the long mark of 6T or above is compared to the long space

portion of 6T or above or the inclination of the reproduction waveform of a reserved area, thereby deciding an optimal recording parameter.

For example, in the case of the space portion,  
5 as shown in Fig. 5, the center of the space portion waveform 501, i.e., in the case of 10T space, for the areas before and after the 5T portion, the straight line 504 connecting peaks 502 and 503 of the each area is made a reference value  $Asp$ . Alternatively, an  
10 average potential between arbitrary two areas within one track of a reserved area is calculated and from the difference, a waveform inclination reference value  $Anw$  of the reserved area is calculated. For example, in the DVD-RAM, as shown in Fig. 6, the inclination 601 is  
15 calculated from the average potentials  $V61$  and  $V62$  of  $n$  sectors of  $m$  sectors ( $m$  and  $n$  are arbitrary numbers) before and after the PID (physical ID) area so as to serve as the reference value  $Anw$ .

Next, as has been calculated in the first  
20 embodiment, the inclinations  $Ax2$ ,  $Ax3$ ,  $Ax5$  at the mark portion are calculated. In this embodiment, the recording parameters are set so that  $Ax2$ ,  $Ax3$ ,  $Ax5$  at the mark portion are substantially matched with the inclinations at the space portion  $Asp$  and  $Anw$ . Fig. 7  
25 shows the reproduction waveform of the mark portion after the actual adjustment. In the same way as in the first embodiment, the inclination of the mark portion of the long mark reproduction waveform is obtained by

the center point 701 and the left and the right peaks 702 and 703. When the obtained inclination 704 is defined for each velocity as Ax2, Ax3, Ax5, the recording parameters are adjusted so that differences  
5 between these inclination values Ax2, Ax3, Ax5 and Asp, Anw are substantially zero as shown by 704 in Fig. 7.

By adjusting the recording parameters by the procedure of this embodiment, the mark shape approaches a uniform ellipse as compared to the long mark of the  
10 first embodiment and it is possible to improve the erase characteristic and cross talk characteristic during overwrite and disk resistance against the rewrite.

[Embodiment 3]

15 Next, explanation will be given on a third embodiment. In this embodiment, the recording parameter setting method and variable velocity recording bit are identical to the first embodiment. However, the method for checking the recording  
20 parameter linearity in the procedures 2 and 4 is different. Hereinafter, explanation will be given on the procedures 2 and 4.

In the procedure 2 of the first embodiment, a difference between the recording parameter obtained by  
25 the linear interpolation and the recording parameter obtained by a condition of the waveform inclination defined for the long mark reproduction waveform of 6T or above is compared to a predetermined error allowance



value to judge the linearity of the recording parameter.

The procedure 2 of the present embodiment calculates only a basic recording parameter (which is made basic recording parameter A) at the medium maximum  
5 recording velocity (5x recording in this embodiment) and a basic recording parameter (which is made basic recording parameter B) at the medium minimum recording velocity (2x recording in this embodiment). A basic recording parameter (which is made basic parameter C)  
10 provided by a medium manufacturer at the recording velocity between them is calculated by linear interpolation of the basic recording parameters A and B.

When this is applied to Fig. 4, 401 is the basic recording parameter A, 402 is the basic recording  
15 parameter B, and 404 is the basic recording parameter C. Next, the area recorded by using the basic parameter C at an adaptive recording velocity of the basic parameter C is reproduced at a predetermined reproduction velocity, for example 2x if DVD-RAM, to  
20 obtain the reproduction jitter. If the jitter value  $\sigma$  is smaller than a predetermined allowance jitter value  $\sigma_r$ , i.e., the adjustment is terminated. If  $\sigma > \sigma_r$ , in the same way as in the first embodiment, "the recording parameter is re-adjusted by the long mark  
25 reproduction waveform" and "the recording medium is improved by considering the recording medium composition and material".

In the procedure 4, in the same way as in the

procedure 2, from the recording parameter obtained by the medium maximum recording velocity and the minimum recording velocity, the recording parameter provided by the medium manufacturer is interpolated at the

5 recording velocity between them. The reproduction jitter  $\sigma_s$  as a result of recording by the recording parameter is compared to a predetermined allowance jitter value  $\sigma_{rs}$  so as to check the linearity of the recording parameter.

10 In the procedure of the present embodiment, there is no need of extracting basic recording parameters other than at the maximum recording velocity and the minimum recording velocity or other recording parameters. Accordingly, it is possible to reduce the  
15 basic recording parameters and the time required for deciding the basic recording parameters.

Moreover, in this embodiment, for interpolating the basic recording parameters and other recording parameters, the basic recording parameters at  
20 the maximum recording velocity and the minimum recording velocity specified in the medium and other recording parameters are calculated. However, it is also possible to perform interpolation by interpolation and extrapolation of basic recording parameters at two  
25 or more arbitrary different velocities provided by the medium manufacturer and other recording parameters.

[Embodiment 4]

Next, explanation will be given on a drive

according to the present invention as a fourth  
embodiment of the present invention. Fig. 10 shows an  
example of processing procedure of the drive performing  
variable velocity recording on a disk having  
5 description of advised recording parameters for a  
plurality of recording velocity.

Fig. 11 shows configuration of the drive  
according to the present embodiment. In the drive of  
the present embodiment, a laser diode 111 is driven by  
10 a laser driver (LDD) 1121 mounted on a pickup 110 and a  
laser beam is emitted from an objective lens 113. The  
laser emission timing is controlled by a waveform  
parameter controller in a DSP 105. It should be noted  
that in this embodiment the waveform controller is  
15 built in the DSP but it may also be a separate chip or  
mounted on the LDD.

The reproduction signal is introduced from  
the pickup through RF F/E LSI 104 into the waveform  
acquisition section in the DSP and a waveform analyzer  
20 so as to be subjected to waveform processing. In the  
waveform acquisition section, acquired waveform data is  
A/D converted to obtain digital data, which is sent to  
the waveform analyzer. Moreover, a part of data is  
acquired directly by a microcomputer 106, which  
25 performs waveform analysis. Furthermore, in the DSP, a  
variable velocity recording flag detection function is  
provided to judge presence/absence of the flag. It  
should be noted that presence/absence of the flag can

also be judged by the microcomputer and the flag detection function need not necessarily be provided in the DSP.

Procedure 1. Checking the variable velocity  
5 recording

Firstly, check is made to determine whether the variable velocity recording flag shown in procedure 5 of the first embodiment is recorded on the medium to be reproduced (step 1003). When the variable velocity  
10 recording flag is ON in the medium (medium which can cope with variable velocity recording), according to the recording parameter at a particular linear velocity recorded on the medium, a recording parameter value at a linear velocity other than that is calculated by  
15 linear calculation so as to perform variable velocity recording (steps 1004-1008).

Procedure 2. Checking the linearity of the recording parameter advised by the medium manufacturer

When the variable velocity recording flag is  
20 OFF or the variable velocity recording flag is not set, linearity is checked between the basic recording parameter advised by the medium manufacturer and advised not to be modified in the drive and the recording velocity (step 1009). It should be noted  
25 that the check method may be, for example, the method shown in the procedure 2 of the first embodiment of the present invention in which a predetermined recording parameter error value is defined or the method shown in

the procedure 2 of the third embodiment of the present invention in which a predetermined jitter allowance value is defined.

When the linearity can be confirmed, variable  
5 velocity recording such as CAV recording is performed while interpolating the recording parameter at each linear velocity from the recording parameters read out from the medium (steps 1004-1008).

When the linearity cannot be confirmed, by  
10 using a part of the recording parameters recorded on the medium, the basic recording parameters and other recording parameters are extracted (step 1010).

Procedure 3. Extracting the basic recording  
parameter by the long mark waveform and checking the  
15 linearity

By using recording parameters at a plurality of recording velocities provided by the medium manufacturer, long mark recording and long space recording of 6T or above are performed at each  
20 recording velocity. In the area where they are recorded, a reproduction waveform of a long mark of 6T or above is extracted and in the same way as is defined in the first embodiment, the inclination of the long mark reproduction waveform when reproduction is  
25 performed at a constant velocity is measured. The recording parameters for the long mark and long space of 6T or above are adjusted so that the inclinations of the long mark reproduction waveform at the respective

recording velocity are substantially matched. This recording parameter corresponds to the basic recording parameter in the first embodiment.

As for the measurement method for measuring  
5 the long mark reproduction waveform inclination, for example, in the case of DVD-RAM, there is a method for extracting the sync pattern 14T in the drive and generating the sample pulses shown in 802 and 803 for the 14T mark reproduction waveform 801 as shown in Fig.  
10 8. Since the sync pattern repeatedly appears at the same timing, it is possible to generate such a sample pulse. This sample pulse generates a window at identical positions at the both sides of the center of the 14T mark reproduction waveform with an identical  
15 width. By calculating a difference  $V$  between voltage values  $V_1$  and  $V_2$  of the hold signals 804 and 805 held only during the window period of the sample pulses 802 and 803, the value obtained is defined as the inclination of the long mark reproduction waveform.

20 Moreover, there is another method for measuring the inclination. As shown in Fig. 9, the reproduction waveform 901 is AD converted by a reproduction clock cycle, for example. From the sampling sequence obtained, a predetermined long mark  
25 reproduction waveform, i.e., 14T reproduction waveform in this case, is extracted. At the positions at an identical distance of time width from the time center of the long mark waveform, average values of the sample

values 902, 903 of the identical number of samples are calculated. A difference between the obtained average values is defined as the inclination of the long mark reproduction waveform. By using one of these methods,  
5 a linearity parameter is decided.

Furthermore, for confirmation of the basic recording parameters obtained in the respective recording velocities, recording is actually performed to check the linearity (step 1011). The check can be  
10 performed by using the method of the procedure 3 described in the first and the second embodiment. If the linearity of the basic recording parameters cannot be confirmed by this procedure, return to the procedure 2 and modify the inclination of the long mark  
15 reproduction waveform. If the linearity of the basic parameters cannot be confirmed even by this, only the constant velocity recording such as CLV is performed (step 1013).

The extraction of the basic recording  
20 parameters and linearity check are preferably performed while performing comparison to the data to clock jitter (hereinafter, referred to simply jitter) during reproduction of the recording waveform and the standard value of the reproduction waveform asymmetry.

25 Procedure 4. Shift table, Power level adjustment

After adjustment of the basic recording parameters, adjustment of recording parameters other

than the basic recording parameters adjusted in the respective velocities in the procedure 2 is performed. Here, in the same way as in the first embodiment, the basic recording parameters adjusted in the procedure 2  
5 are not modified. As the adjustment method, various techniques can be suggested. It is also possible to use the method defined in the medium standard such as the DVD-RAM.

Procedure 5. Checking the recording  
10 parameter linearity

For the recording parameters at the respective recording velocities extracted in the procedure 3, linearity for the recording velocity is checked. In this case also, in the same way as in the  
15 procedure 2 of the first embodiment, the respective recording parameter values may have errors caused by rounding. Accordingly, in the same way as the procedure 2, an allowance error value is set for each of the recording parameters to check the linearity.

20 The drive having the aforementioned procedures have the following advantages.

1. By referencing the variable velocity recording flag, it is possible to easily identify the medium supporting the variable velocity recording.
- 25 2. When a medium supporting variable velocity recording is identified, the write strategy setting becomes easy when performing the variable velocity recording such as CAV and it becomes possible to reduce



the write strategy learning time.

3. By referencing the variable velocity recording flag, in a medium not supporting variable velocity recording, it is possible to prevent recording failure when performing the variable velocity recording by using the recording parameter provided by a medium manufacturer.

4. Even in a medium not provided with a recording parameter corresponding to variable velocity recording from a medium manufacturer, by using the aforementioned procedures, it is possible to obtain the write strategy and a recording parameter corresponding to the variable velocity recording and realize variable velocity recording such as CAV recording.

It should be noted that by holding the recording parameters obtained by the present procedures in the drive such as in the EEPROM, it is possible to rapidly set the recording parameters when the same medium is inserted into the drive, thereby reducing the recording parameter learning time.

Moreover, in the above, instead of performing variable velocity recording according to the recording parameters provided by the medium manufacturer, it is possible to perform variable velocity recording by using the learning result of recording parameter optimal for the drive by using the method defined by the medium standard according to the recording parameters provided by the medium manufacturer instead

of the recording parameters provided by the medium manufacturer.

[Embodiment 5]

Next, explanation will be given on a fifth  
5 embodiment. In this embodiment, the recording  
parameter setting method and the variable velocity  
recording bit are identical to the first embodiment,  
but the recording parameter linearity check in the  
procedures 2 and 4 are different. Hereinafter,  
10 explanation will be given on the procedures 2 and 4 of  
this embodiment.

This embodiment is characterized in that when  
checking the linearity of the parameter defining the  
time-axis direction information of the recording pulse  
15 with respect to the recording velocity in the procedure  
2 and 4 of the first embodiment, a value of the  
parameter normalized by the recording clock cycle is  
used. For example, in the case of DVD-RAM, the  
recording parameters to be processed are TFP, TMP, TLP,  
20 TCL, TEFp, TSLP, TSFP, and TELP.

Explanation will be given by making these  
parameters Tpr and using Fig. 12. The recording  
parameter value (Tpr5x) obtained at the maximum  
recording velocity (in this case, 5x recording) and the  
25 recording parameter value (Tpr2x) obtained at the  
minimum recording velocity (in this case, 2x recording)  
are normalized by the recording clock cycle of the  
respective recording velocities to obtain the

normalized recording parameters Tpr5xs and Tpr2xs. The normalization is performed by an equation (1) as follows.

$$\text{Tpr}[n]\text{xs}=\text{Tpr}[n]\text{x}/\text{Tw}[n] \quad \dots (1)$$

In Equation (1), [n] represents times of  
5 speed (recording speed) and Tw[n] represents a recording clock cycle at the n times of speed. The Tpr5xs is shown by 1201 in Fig. 12. Similarly, Tpr2xs is shown by 1202 in Fig. 12.

These are used to calculate the normalized  
10 recording parameter value 1204 (Tpr3xs\_I) of the speed (3x recording in this case) at which recording parameter is provided by the medium manufacturer. By calculating a difference  $\Delta\text{Tpr3xs}$  1206 between the Tpr3xs\_I and the aforementioned speed obtained by the  
15 procedures 1 and 2 shown in the first embodiment, i.e., the 3x recording parameter value (Tpr3x) in this case which is normalized into a normalized recording parameter value Tpr3xs (1203 in Fig. 12) by Equation (1), the difference is compared to an error allowance  
20 value for the predefined normalized recording parameter, thereby judging the adjustment end.

Thus, it is possible to check the linearity with the recording pulse time-axis direction information not depending on the recording velocity,  
25 thereby facilitating to assure the linearity.

It should be noted that in this embodiment, comparison with the error allowance value is performed by using the difference of the normalized recording parameter values but it is also possible to return the  
5 Tpr3xs\_I obtained above to the previous time information Tpr3x\_I by Equation (2) as follows, calculate the difference  $\Delta Tpr3x$  with the aforementioned Tpr3x not normalized, and compare the error allowance value for the predefined recording parameter, thereby  
10 judging the adjustment end.

$$Tpr3x\_1 = Tpr3xs\_1 \times Tw[3] \quad \dots (2)$$

[Embodiment 6]

Next, explanation will be given on a sixth embodiment. In this embodiment, the recording parameter setting method and the variable velocity  
15 recording bit are identical to the third embodiment but the recording parameter linearity check method in the procedures 2 and 4 is different. Hereinafter, explanation will be given on the procedures 2 and 4 of the present embodiment.

20 This embodiment is characterized in that when checking the linearity for the recording velocity of the parameter defining the recording pulse time-axis direction information in the procedures 2 and 4 of the third embodiment, the value of the parameter normalized  
25 by the recording clock cycle is used. The method

explained in the fifth embodiment is used to obtain the normalized recording parameter  $Tpr3xs\_I$  from the normalized recording parameters  $Tpr5xs$ ,  $Tpr2xs$  and the aforementioned Equation (2) is used to calculate the  
5 time information  $Tpr3x\_I$ . The reproduction jitter  $\sigma_s$  as a result of recording performed with the recording parameter  $Tpr3x\_I$  thus obtained is compared to a predetermined allowance jitter value  $\sigma_{rs}$  to check the linearity of the recording parameter.

10 Thus, it is possible to check the linearity with the recording pulse time-axis direction information not depending on the recording velocity, thereby facilitating to assure the linearity.

[Embodiment 7]

15 Next, explanation will be given on a seventh embodiment. This embodiment is characterized in that when calculating the recording parameter for performing variable velocity recording in the procedure 1 of the fourth embodiment of the present invention, linearity  
20 calculation is performed by using the parameter normalized by the recording clock cycle using the method shown in the fifth embodiment of the present invention.

Moreover, in the recording parameter  
25 linearity checks in the procedures 2 to 4 in the fourth embodiment of the present invention, check of the recording parameter linearity indicating the time information is performed by using the parameter

normalized by the recording clock cycle using the method shown in the fifth embodiment of the present invention.

Thus, it is possible to check the linearity  
5 with the recording pulse time-axis information not depending on the recording velocity and facilitate to assure the linearity.

It should be noted that the long mark and long space of 6T or above in the aforementioned  
10 embodiments intend for mark length and space length in which voltage of the waveform mark portion and space portion during reproduction is not affected by the preceding and following marks and spaces. This can also be defined as a mark and space of one or more  
15 times of the laser spot diameter focused on the recording medium. For example, when the laser spot diameter is 1  $\mu\text{m}$  in the DVD-RAM recording apparatus, this is equivalent to the length of 7.14T. That is, it is also possible to perform the aforementioned  
20 procedures by using a long mark and a long space of 8T or above.

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the  
25 invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.